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ABSTRACT

One of a set of fourteen instructional outlines for use in a course to train novice firemen, this guide covers the topic of fire streams. The various types of fire streams are identified as well as the methods used to produce them, emphasizing the operation of nozzles and the different kinds of friction loss. Designed to be used with the Robert J. Brady Transparencies and the International Fire Service Training Association's manual, "Fire Stream Practices" (see note), this outline refers to the appropriate page and transparency numbers as guides. (An outline of the whole course covering all fourteen topics briefly is provided in the first volume of the set--CE 016 662.) (ELG)

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FIRE STREAM PRACTICES

PURPOSE AND SCOPE

A careful study of fire streams is of importance to every firefighter since this is his most versatile weapon of attack against fire. Often the skillful, tactical and technical utilization of fire streams is the deciding factor in the saving of lives and the protection of property. Because of the importance they play, the firefighter must be familiar with the characteristics and purposes of the many types of fire streams and the method used in producing them.

This outline attempts to present accepted principles and practices of fire streams in a manner that will provide a sound basis for training.

This outline was developed to be used in conjunction with the International Fire Service Training Association Manual Fire Stream Practices and the Robert J. Brady Transparencies.

Course Outline	Guides
I. Fire Streams - definition and purpose	Brady Transparencies Unit 4, Sec. 1 No. 2
A. Definition - A fire stream is considered to be a stream of water from a fire hose after it leaves the nozzle and until it reaches the desired point or fire. This stream of water during the time it passes through space is influenced by the forces of nature, such as gravity, wind velocity and friction with the air. The condition of the stream when it leaves the nozzle is influenced by operating pressures, nozzle design, nozzle adjustment, and the condition of the nozzle tip.	
B. Purpose - To extinguish fire by reducing temperature and to provide protection by --	Brady Transparencies Unit 4, Sec. 1 No. 1
1. Direct application - to extinguish fire by applying water directly to the burning material	
2. Indirect application - to reduce high temperatures and to disperse hot smoke and gases by applying water into the heated area	
3. To reduce temperature over large open fires so as to effect extinguishment	
4. To protect exposures by providing a water curtain	
II. Extinguishing properties of water	
A. Composition of water - Water is a compound of hydrogen and oxygen and is produced by combining two parts hydrogen and one part oxygen, by volume. Hence, the formula H_2O.	Brady Transparencies Unit 4, Sec. 1 No. 3
B. The heat-absorbing ability of water	
1. Water has the ability to absorb large amounts of heat and is the best of all extinguishing materials.	
2. Natural laws affecting use of water as an extinguishing agent:	
a. The law of heat flow - specifies that heat tends to flow from a hot substance to a cold substance.	Fire Stream Practices Pages 7 & 8 Brady Transparencies Unit 4, Sec. 1 No. 1

Course Outline	Guides
b. The law of specific heat - From a fire protection standpoint, specific heat is a measure of the heat-absorbing capacity of a substance. Amounts of heat are measured in terms of British Thermal Units (BTU's). A BTU is defined as the amount of heat needed to raise the temperature of one pound of water one degree fahrenheit.	Fire Stream Practices Page 8, Fig. 1 Brady Transparencies Unit 4, Sec. 1 No. 5
c. Latent heat of vaporization - the quantity of heat absorbed by a substance when it changes from a liquid to a vapor.	Brady Transparencies Unit 4, Sec. 1 No. 6
C. Conversion of water into steam	Brady Transparencies Unit 4, Sec. 1 No. 7
1. When water absorbs enough heat it changes to a vapor called steam.	
2. Characteristics of water vaporization	
a. At sea level water boils at 212°F when it vaporizes or turns into steam.	
b. From temperatures of 70°F to 212°F, water will absorb approximately 142 BTU's per pound.	
c. Water will absorb an additional 970 BTU's per pound of water after it is converted into steam - or a total of 1,112 BTU's per pound.	
d. Therefore, a gallon of water (8.33 lbs. per gallon) at 70°F will absorb more than 9,000 BTU's of heat if all the water is converted into steam.	
e. If the water from a 100 GPM fog nozzle is projected into a heated area, it has the ability to absorb more than 900,000 BTU's of heat per minute.	
D. Relative expansion of water fog when converted into steam	
1. When water changes into steam, it expands approximately 1,700 times its volume.	
2. When 1 cubic foot of water (7.5 gallons) is converted into steam, it expands to 1,700 cubic feet of space.	

Course Outline	Guides
(Example: A 75 GPM fog nozzle expelling 75 gallons of water fog every minute into a heated area and being converted into steam. During one minute of operation, 10 cubic feet of water will have been vaporized, and the 10 cubic feet of water will have expanded to approximately 17,000 cubic feet of steam.)	Brady Transparencies Unit 4, Sec. 1 No. 8
III. Requirements for Fire Streams	
A. Fire stream requirements determined by	Brady Transparencies Unit 4, Sec. 1 Nos. 9 & 10
1. Nature of material burned	
a. Class A fire	
b. Class B fire	
c. Class C fire	
d. Class D fire	
2. Volume of fuel	
3. Form of fuel	
4. Phase of fire	
5. Accessibility of fire	
B. Requirements for extinguishing a building fire	
1. Confined fire	Brady Transparencies Unit 4, Sec. 1 No. 11
a. Incipient phase	
b. Free burning phase	
c. Smouldering phase	
2. Open fire	Brady Transparencies Unit 4, Sec. 1 No. 12

Course Outline	Guides
C. Requirements for extinguishing flammable liquid fires	Brady Transparencies Unit 4, Sec. 1
1. Flash point	No. 13
2. Ignition temperature	
D. Requirements for extinguishing fires involving energized electrical equipment	Brady Transparencies Unit 4, Sec. 1 No. 14
IV. Principle of Pressure	
A. How pressure acts on fluid Note: Instructor should explain and demonstrate each principle.	Fire Stream Practices Pages 15 & 16
1. Fluid pressure is perpendicular to any surface on which it acts.	Brady Transparencies Unit 4, Sec. 1 No. 15
2. Fluid pressure at a point in a fluid at rest is of the same intensity in all directions.	No. 16
3. Pressure applied to a confined fluid from without is transmitted equally in all directions.	No. 17
4. The pressure of a liquid in an open vessel is proportional to its depth.	No. 18
5. The pressure of a liquid in a open vessel is proportional to the density of the liquid.	No. 19
6. The pressure of a liquid on the bottom of a vessel is independent of the shape of the vessel.	No. 20
B. Types of pressure	Brady Transparencies Unit 4, Sec. 1
1. Static pressure	No. 21
2. Normal operating pressure	
3. Residual pressure	
4. Flow pressure	

Course Outline	Guides
5. Derivation of P.S.I.	Brady Transparencies Unit 4, Sec. 1 No. 22 Fire Stream Practices Page 17, Figs. 3 & 4
C. Pressure or friction loss	Brady Transparencies Unit 4, Sec. 1 Nos. 23, 24, & 25
1. Four principles of friction loss in hose and pipe	
a. All other conditions being equal, the loss by friction varies directly with the length of the hose or pipe.	
b. When the same size hoze is used, the friction loss will vary approximately with the square of the velocity of the flow.	
c. For the same discharge, friction loss varies inversely as the fifth power of the diameter of the hose.	
d. For a given velocity of flow, the friction loss in hose is approximately the same no matter what the pressure of the water may be.	Fire Stream Practices Page 19, Figs. 5 & 6 Pages 20 & 21 Figs. 7 & 8
2. Rules for reducing friction loss	
a. Check for rough linings in old hose.	
b. Replace crushed couplings.	
c. Eliminate sharp bends.	
d. Use adapters only when necessary.	
e. Keep valves and nozzles fully open when possible.	
f. Use proper size gaskets	
g. Use short lines when possible.	
h. Use large hose or multiple lines when flow must be increased.	

Course Outline	Guides
3. Pressure loss or gain because of elevation	Fire Stream Practices Page 22, Fig. 9 Brady Transparencies Unit 4, Sec. 1 No. 26
4. Water hammer	Brady Transparencies Unit 4, Sec. 1 No. 27
V. Characteristics of Good Fire Streams	
A. Influencing factors	
1. Available water	
2. Fire equipment	
3. Fire apparatus	
4. Human ability	
B. Types of fire streams	
1. Classified according to volume	
a. Small stream - discharges less than 40 GPM	
b. Hand stream - discharges 40 to 350 GPM	
c. Master stream - discharges more than 350 GPM	
2. Classified according to stream characteristics	
a. Solid stream	
b. Broken stream	
c. Fog or spray stream	
C. Characteristics of streams	
1. Characteristics of good solid streams	Fire Stream Practices Pages 25, 26 & 27 Figs. 10, 11 & 12 Brady Transparencies Unit 4, Sec. 1 No. 28
a. Continuity	
b. Compactness	

Course Outline	Guides
c. Stiffness	
d. Velocity	
2. Characteristics of good broken streams	
a. Ability to cover most space provided	
b. Afford sufficient heat absorption	
c. Adequate volume	
3. Characteristics of good fog streams	
a. Proper jet velocity	Fire Stream Practices Page 28, Figs. 13 &14
b. Proper water particle size	Fire Stream Practices Page 29, Figs. 15 &16
c. Proper volume of water discharge	
d. Sufficient reach	
e. Occupies proper space	Fire Stream Practices Page 30 Reference Sheet No. 1
VI. Developing Fire Streams	
A. Nozzle Pressure	
1. Solid stream nozzles - 50 - 65 P.S.I.	
2. Master stream nozzles - 80 - 100 P.S.I.	
3. Fog stream nozzles - 80 - 100 P.S.I.	
B. Symbols and terms	Brady Transparencies Unit 4, Sec. 2 Nos. 1, 3
1. Gallons per minute - GPM	
2. Pounds per square inch - P.S.I.	
3. Friction loss - F.L.	
4. Nozzle pressure - N.P.	
5. Flow pressure - P	

Course Outline

Guides

6. Engine pressure - E.P.

7. Volume and velocity - V

8. Pi - π

9. Square root - $\sqrt{\ }$

10. To square a number - N^2

11. Constants - K

12. Hose length (50 foot section) - L

C. Measurements

1. One gallon of water contains 231 cubic inches.

2. One cubic foot of water contains 1, 728 cubic inches. (A cubic foot is 12 inches long, 12 inches wide, and 12 inches high; therefore it contains 12" x 12" x 12" or 1,728 cubic inches.)

3. One cubic foot of water weights approximately 62.5 pounds.

4. One cubic foot of water contains 7,481 gallons or 7.5.

5. One gallon of water weights 8.33 pounds.

6. Atmospheric pressure at sea level is 14.7 P.S.I.

7. A column of water 1 inch square and 1 foot high will create a pressure of .434 pounds.

8. A pressure of 1 pound per square inch will raise a column of water 2.304 feet.

VIII. Calculating Fire Streams

Brady Transparencies
Unit 4, Sec. 2
No. 7

A. Computing water flow in gallons per minute

1. Refer to tables for water flow from a given size orifice.

Fire Streams Practices
Page 129

Course Outline

Guides

2. Calculate flow by using formula when flow pressure is known.

3. Formula:
$29.7 \times D^2 \times \sqrt{P}$

29.7 is a constant derived from natural laws of physics. (For practical purposes, 30 can be used.)

D is diameter of orifice in inches.

P is pressure in P.S.I. read by a pitot tube and gauge at the orifice

Brady Transparencies
Unit 4, Sec. 2
No. 6

B. Computing friction loss in $2\frac{1}{2}$ inch hose

Fire Stream Practices
Pages 43 & 44
Brady Transparencies
Unit 4, Sec. 2
No. 8

1. Measured per 100 feet of hose

2. Governed by amount of water flowing

3. Formula when more than 100 GPM is flowing

$F.L. = 2\,Q^2 + Q$

F.L. = Friction loss

$Q = \frac{\text{Amount of water flowing in GPMs}}{100}$

4. Formula when less than 100 GPM is flowing

Fire Stream Practices
Page 45

$F.L. = 2\,Q^2 + \frac{1}{2}Q$

F.L. = Friction loss

$Q = \frac{\text{Amount of water flowing in GPMs}}{100}$

C. Computing Engine Pressure

E.P. = N. P. - F.L. (plus or minus elevation)

Fire Stream Practices
Page 44
Brady Transparencies
Unit 4, Sec. 2
Nos. 4 & 5

E.P. = Engine pressure (pump pressure)

N. P. = Nozzle pressure

F. L. = Friction loss

Course Outline

Guides

D. Friction loss due to elevation

Brady Transparencies
Unit 4, Sec. 2
No. 9

1. One-half P.S.I. per foot elevation, positive or negative

2. Add 5 P.S.I. to engine pressure for every floor above ground level water is to be elevated.

E. Computing Friction loss in hose other than $2\frac{1}{2}$ inch

Fire Stream Practices
Pages 45 & 46
Brady Transparencies
Unit 4, Sec. 2
Nos. 10, 11 & 14

1. Governed by amount of water flowing

2. Measured per 100 feet of hose

3. Conversion factors used

4. Friction loss in other than $2\frac{1}{2}$ inch hose, with the same amount of water flowing is obtained by dividing or multiplying the friction loss in $2\frac{1}{2}$ inch hose by a conversion factor for the hose desired.

5. Conversion factors

Diameter	Divide By	Multiply By
Single Lines		
$\frac{3}{4}$ - inch chemical hose	.0029	344
1 - inch chemical hose	.011	91
$1\frac{1}{4}$ - inch rubber lined hose	.025	40
$1\frac{1}{2}$ - inch rubber lined hose	.074	13.5
$1\frac{1}{4}$ - inch unlined linen hose	.0157	63.6
$1\frac{1}{2}$ - inch unlined linen hose	.039	25.6
2 - inch unlined linen hose	.16	6.25
$2\frac{1}{2}$ - inch unlined linen hose	.47	2.13
2 - inch rubber lined hose	.34	2.94
3 - inch rubber lined hose	2.6	.385
3 - inch hose with $2\frac{1}{2}$" couplings	2.5	.4
$3\frac{1}{2}$ - inch rubber lined hose	5.8	.172
4 - inch rubber lined hose	11.0	.09
$4\frac{1}{2}$ - inch rubber lined hose	19.5	.051
5 - inch rubber lined hose	32.0	.031

	Divide By	Multiply By
Siamesed Lines of Equal Length		
2 - $2\frac{1}{2}$ - inch	3.6	.28
3 - $2\frac{1}{2}$ - inch	7.75	.129
2 - 3 - inch	9.35	.107
1 - 3 - inch and 1 - $2\frac{1}{2}$ - inch	6.1	.164
2 - $2\frac{1}{2}$ - inch and 1 - 3 - inch	11.5	.087
2 - 3 - inch and 1 - $2\frac{1}{2}$ - inch	15.0	.067
Standpipes		
4 inches	7.5	.133
5 inches	22	.045
6 inches	52	.019

6. Formulas

F.L. = 2 Q^2 + Q x or ÷ conversion factor

F.L. = 2 Q^2 + $\frac{1}{2}$Q x or ÷ conversion factor

Course Outline

Guides

F. Computing friction loss for more than one line of the same length off the same pumper

Fire Stream Practices
Pages 46 & 47
Brady Transparencies
Unit 4, Sec. 2
No. 12

1. If nozzles are same, the flow is equal and resistance will be the same.

2. Figure only one line and the other line will have approximately the same pressure.

3. While speed of pump will be increased to deliver additional water, the discharge pressure will remain the same.

G. Computing friction loss for more than one line of unequal length off the same pumper

Fire Stream Practices
Pages 48 & 49

1. Determine desired pressure for each hose line seperately and operate pumper at highest pressure needed.

2. Reduce pressure on line requiring lower pressure by partially closing discharge gate.

H. Computing friction loss in wyed lines ($1\frac{1}{2}$ inch lines wyed from a $2\frac{1}{2}$ inch)

Fire Stream Practices
Pages 49 - 53

Brady Transparencies
Unit 4, Sec. 2
No. 13

I. Computing friction loss in preconnected hose

Fire Stream Practices
Page 50

	GALLONS PER MINUTE FLOW																		
Size of Fire Hose	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Friction Loss Per 100' - 3/4" Rubber Hose	14	29	50	(Not Practical)															
Friction Loss Per 100' - 1" Rubber Hose	4	7	12	19	26	35	44			(Not Practical)									
Friction Loss Per 100' - 1-1/2" C. R. L. Hose		1	2	3	4	5	6	8	9	11	13	15	17	20	22	25	28	31	33

J. Computing friction loss in siamesed lines

Fire Stream Practices
Pages 54 & 55
Brady Transparencies
Unit 4, Sec. 2
No. 15

Course Outline	Guides
K. Fog Streams and friction loss	
1. Principles involved with fog nozzles are essentially the same as those for solid streams. One difference is that the discharge opening area of the fog nozzle is not known. (For fog nozzle flows refer to manufacturer's information.)	
2. Variable opening nozzles	
3. Variable flow nozzles	
4. Constant flow nozzles	
5. Constant pressure nozzles	
VIII. Fire Stream Rules of Thumb	
A. Condensed Q Formula	Fire Stream Practices Page 57 Brady Transparencies Unit 4, Sec. 2 No. 17
1. Used for 3 inch hose with $2\frac{1}{2}$ inch couplings	
2. Friction loss = Q^2	
$Q = \frac{GPM}{100}$	
B. Friction loss by association - for solid streams from $2\frac{1}{2}$ inch hose	Fire Stream Practices Pages 58 & 59

APPROXIMATE CAPACITIES OF SOLID STREAM NOZZLES

Booster and $1\frac{1}{2}$-Inch Lines			$2\frac{1}{2}$-Inch Lines			Master Streams		
Tip Size	50 p.s.i.	65 p.s.i.	Tip Size	50 p.s.i.	65 p.s.i.	Tip Size	80 p.s.i.	100 p.s.i.
$\frac{1}{4}$-Inch	12	15	$\frac{3}{4}$-Inch	100	150	$1\frac{1}{4}$-Inch	400	500
$\frac{3}{8}$-Inch	25	30	$\frac{7}{8}$-Inch	150	200	$1\frac{3}{8}$-Inch	500	600
$\frac{1}{2}$-Inch	50	60	1 -Inch	200	250	$1\frac{1}{2}$-Inch	600	700
$\frac{5}{8}$-Inch	75	90	$1\frac{1}{8}$-Inch	250	300	$1\frac{5}{8}$-Inch	700	800
			$1\frac{1}{4}$-Inch	300	350	$1\frac{3}{4}$-Inch	800	900
						$1\frac{7}{8}$-Inch	900	1000
						2 -Inch	1000	1200

Course Outline | Guides

RULE OF THUMB FRICTION LOSS FOR SOLID STREAMS FROM $2\frac{1}{2}$ -INCH HAND-LINES

Nozzle Size (inches)	Nozzle Pressure	Actual Gallons Per Minute	Gallons Per Minute to Remember	Basic Friction Loss Per 100 Feet Of Hose (Approximate Pounds Per Square Inch)
$\frac{3}{4}$ -Inch	50	118	100	3
$\frac{7}{8}$ -Inch	50	159	150	7
1 -Inch	50	209	200	10
$1\frac{1}{8}$ -Inch	50	265	250	18
$1\frac{1}{4}$ -Inch	50	326	300	25

RULE OF THUMB FRICTION LOSS BY ASSOCIATION

Tip Size	Number to be Remembered	Approximate Friction Loss Per 100 Feet	Approximate Gallons Per Minute
$\frac{3}{4}$ -Inch	Tip suggests 3	3 p.s.i.	100
$\frac{7}{8}$ -Inch	Tip suggests 7	7 p.s.i.	150
1 -Inch	Tip suggests 10	10 p.s.i.	200
$1\frac{1}{8}$ -Inch	Tip suggests 18	18 p.s.i.	250
$1\frac{1}{4}$ -Inch	Tip suggests 25	25 p.s.i.	300

C. Friction loss by fractions - for 100 feet of $2\frac{1}{2}$ inch hose for solid streams

3/4 inch tip - F.L. equals 1/12 of nozzle pressure
7/8 inch tip - F.L. equals 1/7 of nozzle pressure
1 inch tip - F.L. equals 1/5 of nozzle pressure
1 1/8 inch tip - F.L. equals 1/3 of nozzle pressure
1 1/4 inch tip - F.L. equals 1/2 of nozzle pressure

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Brady Transparencies
Unit 4, Sec. 2
No. 18

D. Friction loss by GPM flowing

Fire Stream Practices
Pages 59 & 60
Fig. 24
Brady Transparencies
Unit 4, Sec. 2
Nos. 19A & 19B
Reference Sheet #2, 3

E. Friction loss by counting

Fire Stream Practices
Pages 60 & 61
Fig. 25
Brady Transparencies
Unit 4, Sec. 2
No. 20
Reference Sheet #4

Course Outline

Guides

F. Suction hose friction loss

Fire Stream Practices
Page 56
Brady Transparencies
Unit 4, Sec. 2
No. 16
Reference Sheet #5

IX. Master Streams

Reference Sheet #6

A. A master stream is any of a variety of heavy streams formed by siamesing two or more big hose lines into a heavy stream device. The term "master stream" is applied to any fire stream that is too large to be controlled without mechanical aid.

B. Nature of master streams

1. Solid

a. Volume

b. Reach

2. Fog

a. Volume

b. Reach

C. Master stream devices

1. Turret pipe

2. Deluge set

3. Monitor

4. Ladder pipe

5. Water tower

D. Producing master streams

Brady Transparencies
Unit 4, Sec. 2
No. 21

1. Know nozzle tip size for solid streams

Course Outline

Guides

2. Know GPM for each tip at 80 P.S.I.

3. Know GPM flow for fog nozzles at 100 P.S.I.

E. Master stream flow table

Fire Stream Practices
Page 67

Nozzle Size	Pressure	Actual Flow	Flow to Remember
1 1/4	80	413	400
1 7/8	80	500	500
1 1/2	80	596	600
1 5/8	80	700	700
1 3/4	80	813	800
2	80	1063	1000

F. Calculating Friction loss for master streams

Brady Transparencies
Unit 4, Sec. 2
Nos. 22, 23 & 24

1. Single lines of $2\frac{1}{2}$ inch hose (not practical)

2. Siamesed lines of $2\frac{1}{2}$ inch hose

3. Single lines of 3 inch hose

4. Siamesed lines of 3 inch hose

5. Friction loss due to elevation

6. Table

Fire Stream Practices
Page 67

Nozzle Size	F.L. per 100 feet in two $2\frac{1}{2}$ inch hose
1 1/4	1/8 of nozzle pressure
1 3/8	1/5 of nozzle pressure
1 1/2	1/4 of nozzle pressure
1 5/8	1/3 of nozzle pressure
1 3/4	1/2 of nozzle pressure
2	3/4 of nozzle pressure

Course Outline	Guides
X. Relaying Water	Brady Transparencies Unit 4, Sec. 2 Nos. 2 & 5
A. Relay pumping - where two or more pumpers are used in a series so that the entire volume of water from each pumper is passed on to the next pumper in the series	
B. Relay pumping should be used when the distance between the water source and the point where the water is used is so great that it requires excessive pump pressure for a single pumper.	
C. Guide lines for relay pumping operations	
1. Pumpers within a relay should not operate above 200 P.S.I. discharge pressure.	
2. Each pump operator must know the amount of water flowing.	
3. When possible, operate all pumps at approximately the same pressure.	
4. Open and shut nozzles slowly.	
5. When starting the operation, open the pump drain cocks or an unused discharge opening.	
6. Place the longest pumper near the source of water and the smallest pumper at the fire.	
D. Determining distance between pumpers in relay operations	Brady Transparencies Unit 4, Sec. 2 Nos. 26 & 27
1. Rule of thumb for two pumper relay operation	
2. Table for determining distance between pumpers in relay operations	Fire Stream Practices Page 75 Reference Sheet #7
XI. Supplying Private Protection Equipment	
A. Automatic sprinkler systems	Water Supplies for the Fire Service
1. Make sure that pumper is adequate for volume and pressure.	Fire Department Support of Automatic Sprinkler Systems
2. Use two hose lines from the pumper to the fire department connection.	

Course Outline	Guides
3. Build up pressure slowly to 150 P.S.I.	Brady Transparencies Unit 4, Sec. 2 No. 28
4. If one pumper is unable to comply, use two pumpers.	
5. Do not rob the water supply feeding the system.	
6. Check all control valves to the system.	
7. Avoid premature shut-off of sprinkler system.	
8. Maintain the pumper hook-up during overhaul.	
9. See that system is restored.	
B. Standpipe systems	
XIII. Selecting the Fire Stream	Brady Transparencies Unit 4, Sec. 3 Nos. 1 & 2
A. Pre-fire plan	
B. Consider known facts	
C. Size-up	
D. Three-position approach	
1. Streams to protect exposures	
2. Streams at avenues of fire spread	
3. Streams at point of origin	
E. Rate of flow for knock-down of fully involved enclosed area	
$\frac{\text{Cubic Feet}}{100} = \text{GPM}$	Iowa State University Bulletin No. 135 Water for Fire Fighting Fire Stream Practices Page 84
XIII. Application of Water	Brady Transparencies Unit 4, Sec. 3 No. 3
A. Rate of application	
B. Confining and extinguishing fires	

Course Outline	Guides
C. Handling the nozzle	
1. Nozzle kick-back	Brady Transparencies Unit 4, Sec. 3 No. 4
2. Nozzle operation and control precautions	Brady Transparencies Unit 4, Sec. 3 No. 4
a. Nozzles should be inspected for damage and proper operation.	
b. Keep nozzles closed while make up and advancing hose lines.	
c. Do not drop or drag nozzles.	
d. Open and close nozzle slowly to prevent pressure surges and water hammer.	
e. If control of nozzle is lost, step in front of it to prevent being struck by nozzle.	
3. Nozzle operation	Have students operate nozzles using methods described.
a. 1 1/2 inch nozzle operation (one man)	Fire Stream Practices Page 86, Fig. 26
1. Face direction to be used and have hose straight at least 10 feet behind nozzle.	Brady Transparencies Unit 4, Sec. 3 No. 5
2. Hold the nozzle in one hand and brace hose with the other hand.	
3. Anchor the hose to ground by placing the foot nearest the hose upon it.	
b. 1 1/2 inch nozzle operation (two men)	Fire Stream Practices Page 87, Fig. 27
1. Most prefereable for 1 1/2 inch line operation	Brady Transparencies Unit 4, Sec. 3 No. 5
2. Nozzleman holds nozzle with one hand and uses the other hand to brace hose.	
3. Back up man stands 3 to 4 feet behind nozzleman.	

Course Outline	Guides
4. Important function of back-up man is to keep hose line straight behind nozzleman.	
c. 2 1/2 inch nozzle operation (one man)	Fire Stream Practices Page 87, Figs. 28 & 29 Brady Transparencies Unit 4, Sec. 3 No. 5
1. Form a large loop and cross the loop about two feet behind the nozzle.	
2. Nozzleman sits where hose crosses and directs the stream.	
3. Hose may be tied at point of cross to permit greater safety and ease of operation.	
d. 2 1/2 inch nozzle operation (two men)	Fire Stream Practices Page 89, Figs. 30 & 31 Brady Transparencies Unit 4, Sec. 3 No. 6
1. Nozzleman holds nozzle with one hand and braces hose with other against waist.	
2. Back-up man is 3 to 4 feet to rear with knee on hose and his hands bracing it.	
e. 2 1/2 inch nozzle operation (three men)	Fire Stream Practices Page 89, Fig. 32 Brady Transparencies Unit 4, Sec. 3 No. 6
1. Same as above except third man is either placed beside of No. 2 back-up man or between him and nozzleman.	
2. This is the most practical control method.	
4. Maneuvering the nozzle	Fire Stream Practices Page 90, Fig. 33 Brady Transparencies Unit 4, Sec. 3 No. 7
a. Excess bending of hose will cause kinks.	
b. If line is too hard to handle, partially close and regain nozzle control.	
5. Advancing the nozzle	
a. Precautions to be observed when advancing nozzles	
1. Wear protective breathing apparatus	
2. Feel your way when advancing through smoke filled building	
3. Advance in pairs or groups	

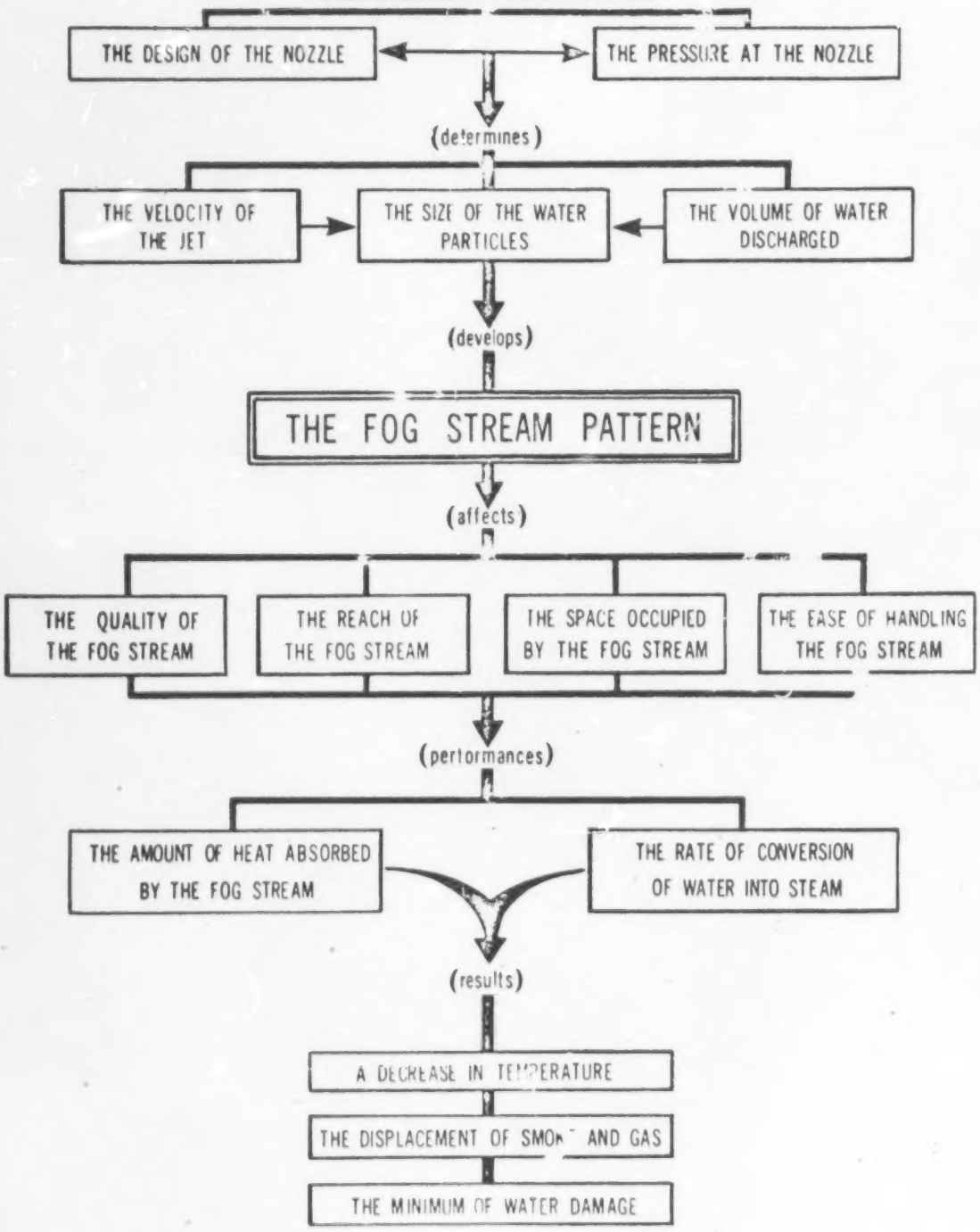
Course Outline	Guides
4. Carry a charged line.	
5. If you must retreat, close nozzle and follow hose line out.	
6. Use water fog when entering highly heated areas.	
7. Where possible use combustible and toxic gas detectors.	
8. Observe proper precautions where radioactive materials are suspected.	
b. Teamwork is required when advancing two or more lines.	Fire Stream Practices Page 91, Figs. 34 & 35
D. Applying the water	
1. Applying small streams	
2. Applying fog streams from hand lines	Fire Stream Practices Page 93
a. On confined structural fire	Reference Sheet #8
b. On open structural fires	
c. On flammable liquid fires	
3. Applying solid streams from hand lines	Fire Stream Practices Page 41, Figs. 39, 40 & 41 Brady Transparencies Unit 4, Sec. 3 No. 10
4. Applying master fog streams	
5. Applying master solid streams	
6. Applying broken streams	
7. Applying water fog for ventilation	Fire Stream Practices Page 96, Fig. 36 Page 97, Figs. 37 & 38 Brady Transparencies Unit 4, Sec. 3 No. 89

Course Outline	Guides
IXV. Nozzle Design and Construction	
A. Mechanical principles of solid stream nozzles	Fire Stream Practices Pages 103 & 104 Figs. 45, 46 & 47 Brady Transparencies Unit 4, Sec. 4 No. 1
1. Rotary motion and twisting currents	
2. Effective range of nozzles	Reference Sheet #9
B. Mechanical principles of fog stream nozzles	Fire Stream Practices Pages 105 & 106 Figs. 48, 49, 50 & 51 Brady Transparencies Unit 4, Sec. 3 No. 2
1. Deflection	
2. Periphery	
3. Impinge	
4. Swirl	
C. Nozzle control valves	Fire Stream Practices Pages 107 & 108 Figs. 52, 53, 54, 55 & 56
1. Solid plug	
2. Ball-valve	
3. Rotary	
XV. Relation Information	
A. Selecting a hydrant for a flow test	Fire Stream Practices Page 113, Fig. 58 Brady Transparencies Unit 4, Sec. 4 No. 7
B. Using the pitot tube and gauge	Fire Stream Practices Page 113, Fig. 59 Brady Transparencies Unit 4, Sec. 4 No. 8

Course Outline	Guides
C. In-line gauges	Fire Stream Practices Page 115, Fig. 60
D. Fire Stream conductivity	Fire Stream Practices Page 115
1. Safety precautions	
2. Distance requirements	Reference Sheet #10
a. Solid stream	
b. Fog stream	

REFERENCE SHEET #1

FACTORS INFLUENCING THE EFFICIENCY OF FOG STREAM NOZZLES


THE DESIGN OF THE NOZZLE
THE PRESSURE AT THE NOZZLE
(determines)
THE VELOCITY OF THE JET
THE SIZE OF THE WATER PARTICLES
THE VOLUME OF WATER DISCHARGED
(develops)
THE FOG STREAM PATTERN
(affects)
THE QUALITY OF THE FOG STREAM
THE REACH OF THE FOG STREAM
THE SPACE OCCUPIED BY THE FOG STREAM
THE EASE OF HANDLING THE FOG STREAM
(performances)
THE AMOUNT OF HEAT ABSORBED BY THE FOG STREAM
THE RATE OF CONVERSION OF WATER INTO STEAM
(results)
A DECREASE IN TEMPERATURE
THE DISPLACEMENT OF SMOKE AND GAS
THE MINIMUM OF WATER DAMAGE

FRICTION LOSS BY GPM FLOWING

G.P.M. FLOWING — 2 1/2" HOSE —	F. L. per 100 ft. — 2 1/2" HOSE —
100	3
110	4
120	4
130	5
140	5
150	6
160	7
170	7
180	8
190	9
200	10
210	11
220	12
230	13
240	14
250	15
260	16
270	17
280	18
290	19
300	20

Flow from 100 to 160 must be remembered

SUBTRACT "10" from the first two numbers of G. P. M.

HAND STREAMS		MASTER STREAMS	
TIP SIZE	G. P. M.	TIP SIZE	G. P. M.
3/4	120	1 1/4	400
7/8	160	1 3/8	500
1	200	1 1/2	600
1 1/8	260	1 5/8	700
1 1/4	320	1 3/4	800
		2	1,000

FRICTION LOSS BY GPM FLOWING

G.P.M. Flowing Booster Hose	F.L. Per 100ft. 1 inch Hose	F.L. Per 100ft. 3/4 inch Hose	G.P.M. Flowing 1 1/2" Hose	G.P.M. Flowing 2 1/2" Hose	F.L. Per 100ft. 1 1/2" or 2 1/2" Hose
10	6	24	50	200	10
11	7	28	55	220	12
12	8	32	60	240	14
13	9	36	65	260	16
14	10	40	70	280	18
15	11	44	75	300	20
16	12	48	80	320	23
17	13	52	85	340	26
18	14	56	90	360	29
19	15	60	95	380	32
20	16	64	100	400	35
21	17	68	105	420	39
22	18	72	110	440	43
23	19	76	115	460	47
24	20	80	120	480	51
25	21	84	125	500	55

SUBTRACT "4"

MULTIPLY THE F.L. in 1" hose by "4"

Same as 4 times as much water flowing in 2 1/2"

For Increase of 20 G.P.M. flowing F.L. increases by 2 P.S.I.

For Increase of 20 G.P.M. flowing F.L. increases by 3 P.S.I.

For Increase of 20 G.P.M. flowing F.L. increases by 4 P.S.I.

FRICTION LOSS BY COUNTING

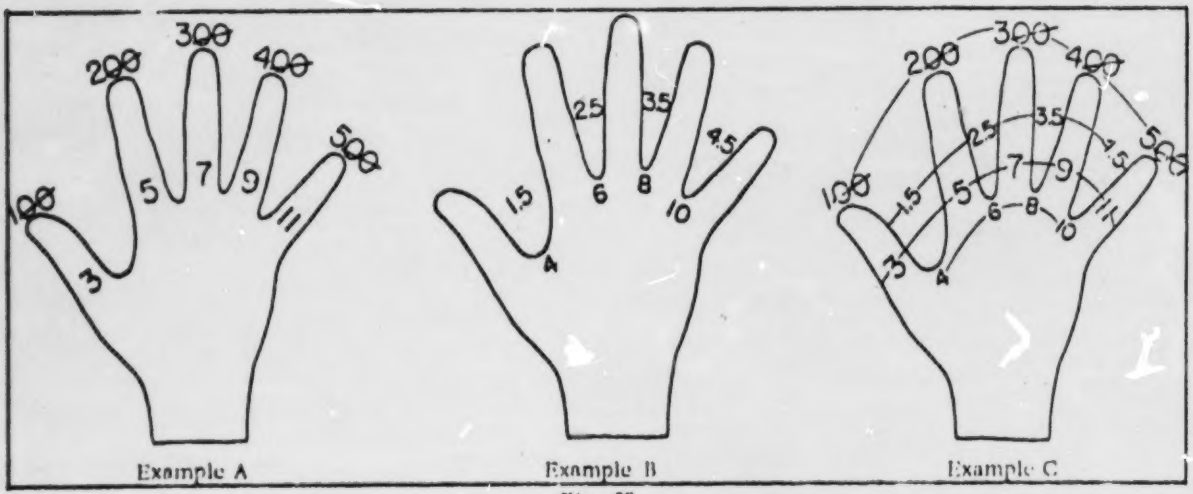


Fig. 89

CALCULATING FRICTION LOSS BY COUNTING

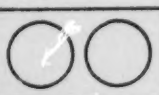
While fire stream calculations for fire ground use should be simple enough to be done mentally, the following method makes it unnecessary to apologize for counting on the fingers. While this method applies only to 2-1/2-inch c.r.l. hose, for flows from 100 to 500 GPM, it will later be seen that this limitation is not objectionable. As illustrated in Example A, Fig. 89, starting with the thumb of the left hand, each finger is numbered at the tip in terms of hundreds of gallons per minute. Returning to the thumb, and again moving from left to right, the base of each finger is given a successive odd number, beginning with three. The friction loss for 100 feet of 2-1/2-inch c.r.l. hose at a desired flow is determined by selecting the finger to which the desired flow has been assigned, and multiplying the number at the tip of the finger by the number at the base of the finger. Thus the friction loss for a flow of 500 GPM can be found by using the numbers assigned to the little finger, or, 5 x 11 = 55 p.s.i. Likewise, the friction loss for a flow of 200 GPM is found by using the numbers assigned to the index finger. Thus, 2 x 5 = 10 p.s.i. friction loss per 100 feet of 2-1/2-inch c.r.l. fire hose.

Since nozzle capacities vary in GPM, the nearest half-hundred can be used with slight variations. The numbers 1.5 2.5, 3.5, and 4.5 can be used for flows of 150, 250, 350, and 450 GPM respectively. These half-hundred figures can be assigned to the spaces between the fingers. Then, by using the even numbers 4, 6, 8, and 10 to couple with the half-hundred figures, sufficiently accurate results can be obtained, Example B. Thus, the friction loss for a 250 GPM flow can be found by multiplying 2.5 x 6 = 15 p.s.i. friction loss per 100 feet of 2-1/2-inch c.r.l. fire hose. The application of both systems to one hand is illustrated in Example C.

REFERENCE SHEET #5

SUCTION HOSE FRICTION LOSS

PRESSURE LOSS DUE TO FRICTION IN 20 FEET OF HARD OR SOFT SUCTION HOSE

SIZE (I.D.)	SQUARE INCH AREA	500 G.P.M. FLOW	750 G.P.M. FLOW
½ in.	— 5 sq. in.	11 p.s.i.	+ 24 p.s.i.
WO ½ in. 	— 10 sq. in.	3 p.s.i.	+ 6 p.s.i.
in.	+ 7 sq. in.	+ 4 p.s.i.	— 10 p.s.i.
in.	+ 12 sq. in.	1 p.s.i.	+ 2 p.s.i.
½ in.	— 16 sq. in.	+ ½ p.s.i.	+ 1 p.s.i.
in.	+ 19 sq. in.	Negligible	Negligible

PRODUCING MASTER STREAMS

PRODUCING MASTER STREAMS

G.P.M. FLOW PER HOSE LINE	FRICTION LOSS PER-100	APPROX. G P M FLOW	NOZZLE PRESSURE P S I	NOZZLE TIP SIZE
400 G.P.M. THROUGH ONE 2 1/2" LINE (NOT PRACTICAL)	36	400	80	1 1/4"
200 / 200 G P M THROUGH TWO 2 1/2" LINES (DESIRABLE)	10			
400 G P M THROUGH ONE 3" LINE (DESIRABLE)	15			
500 G P M THROUGH ONE 2 1/2" LINE (NOT PRACTICAL)	55	500	80	1 3/8"
250 / 250 G P M THROUGH TWO 2 1/2" LINES (DESIRABLE)	15			
500 G P M THROUGH ONE 3" LINE (LESS DESIRABLE)	22			
300 / 300 G.P.M. THROUGH TWO 2 1/2" LINES (LESS DESIRABLE)	21	600	80	1 1/2"
200 / 200 / 200 G. P. M. THROUGH THREE 2 1/2" LINES (DESIRABLE)	10			
300 / 300 G.P.M. THROUGH TWO 3" LINES (DESIRABLE)	8			
350 / 350 G.P.M. THROUGH TWO 2 1/2" LINES (NOT PRACTICAL)	29	700	80	1 5/8"
233 / 233 / 233 G.P.M. THROUGH THREE 2 1/2" LINES (DESIRABLE)	13			
350 / 350 G.P.M. THROUGH TWO 3" LINES (DESIRABLE)	12			
270 / 270 / 270 G.P.M. THROUGH THREE 2 1/2" LINES (LESS DESIRABLE)	18	800	80	1 3/4"
200 / 200 / 200 / 200 G P M THROUGH FOUR 2 1/2" LINES (DESIRABLE)	10			
400 / 400 G.P.M. THROUGH TWO 3" LINES (DESIRABLE)	15			
250 / 250 / 250 / 250 G P M THROUGH FOUR 2 1/2" LINES (DESIRABLE)	15	1000	80	2"
335 / 335 / 335 G.P.M. THROUGH THREE 3" LINES (DESIRABLE)	10			

DETERMINING DISTANCE BETWEEN PUMPERS DURING RELAY OPERATIONS

TABLE TO DETERMINE DISTANCE BETWEEN PUMPERS

DP	IP	AP	GPM	No. Lines	FL/100 Feet	Approx. Lay
150	10	140	200	1	10	1400 feet
			250		15	900 feet
			300		21	650 feet
			350		28	500 feet
200	10	190	200	1	10	1900 feet
			250		15	1250 feet
			300		21	900 feet
			350		28	650 feet
			400		36	500 feet
150	10	140	350	2	8	1650 feet
			400		10	1400 feet
			450		13	1050 feet
			500		15	900 feet
			600		21	650 feet
			700		28	500 feet
200	10	190	400	2	10	1900 feet
			450		13	1450 feet
			500		15	1250 feet
			600		21	900 feet
			700		28	650 feet
			850		40	450 feet

DP	Discharge Pressure
IP	Intake Pressure on next pumper
AP	Available Pressure to overcome friction loss and elevation
GPM	Gallons Per Minute flow
No. Lines	Number of single $2\frac{1}{2}$ -inch lines in relay
FL/100 Feet	Friction Loss per 100 feet of $2\frac{1}{2}$ -inch hose (Table Value)
Approx. Lay	Approximate maximum distance between pumpers

EXTINGUISHMENT OF A CONFINED STRUCTURAL FIRE

ANALYSIS OF THE EXTINGUISHMENT OF A CONFINED STRUCTURAL FIRE

PHASE	CONDITIONS	REQUIREMENTS TO EXTINGUISH	METHOD
1st	Beginning fire. 20% oxygen content of atmosphere. Accelerating heat generation according to development of fire. Considerable smoke in reverse proportion to heat generation. Destruction limited to immediate fire area.	Entrance and direct application of extinguishing agent. Personal protection if needed.	Make entrance. Locate fire. Apply extinguishing agent at base of fire. Protect self with protective breathing equipment. Ventilate at natural openings if needed.
2nd	Flame production. Major involvement. Entrance difficult because of heat. Oxygen reduction 21-15% or less. Rapid heat generation with highest temperature at ceiling. High convection of heated gases and air. Limited smoke production, increasing as flame decreases. Increasing atmospheric pressure within space. Rapid destruction.	Reduction of room temperature to 300°F or less. Entrance and direct application of extinguishing agent to remaining fire. Personal protection if needed.	1. Locate area of major involvement. 2. Determine point or points at which application is to be made. 3. Make opening, if needed, small as possible for application of water fog. 4. Assume position so that nozzleman will not be involved with hot smoke and condensing stream. 5. Apply fog into upper level to meet space requirements. - If applied at upper level use short-reach fog. - If applied at lower level use long-reach fog and direct into upper level. The order of expulsion due to displacement will be: 1st. Smoke 2nd. Smoke and condensing steam 3rd. Condensing steam 6. Continue application of fog without interruption until decrease of condensing steam is noticed. 7. Enter and extinguish remaining fire and spot fires. 8. Protect self if necessary with breathing equipment and heavy clothing.
3rd	Smoldering fire. Oxygen below 15%. Convection ceased and stratification of temperatures, highest at upper level. General decreasing of temperature due to lowering of heat generation and heat losses. Intense smoke production. Serious accumulation of carbon monoxide gas. Chance for atmospheric breathing. Possibility of smoke explosion if air is admitted.	Reduction of temperature. Displacement of smoke and gases with steam to make space livable and eliminate chance for explosion. Entrance and direct application of extinguishing agent. Personal protection if needed.	

REFERENCE SHEET #9

EFFECTIVE RANGE OF SOLID FIRE STREAM

EFFECTIVE RANGE OF SOLID FIRE STREAMS

Showing the distance in feet from the nozzle at which streams will do effective work with a moderate wind blowing. With a strong wind, the reach is greatly reduced.

	SIZE OF NOZZLE									
Nozzle	1-Inch		1 1/8-Inch		1 1/4-Inch		1 3/8-Inch		1 1/2-Inch	
Pressure	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
20	35	37	36	38	36	39	36	40	37	42
25	43	42	44	44	45	46	45	47	46	49
30	51	47	52	50	52	52	53	54	54	56
35	58	51	59	54	59	58	60	59	62	62
40	64	55	65	59	65	62	66	64	69	66
45	69	58	70	63	70	66	72	68	74	71
50	73	61	75	66	75	69	77	72	79	75
55	76	64	79	69	80	72	81	75	83	78
60	79	67	83	72	84	75	85	77	87	80
65	82	70	86	75	87	78	88	79	90	82
70	85	72	88	77	90	80	91	82	92	84
75	87	74	90	79	92	82	93	84	94	86
80	89	76	92	81	94	84	95	86	96	88
85	91	78	94	83	96	87	97	88	98	90
90	92	80	96	85	98	89	99	90	100	91

NOTE: Nozzle pressures are as indicated by Pitot tube. The horizontal and vertical distances are based on experiments by Mr. John R. Freeman, *Transactions* Am. Soc. C.E., Vol. XXI.

FIRE STREAM CONDUCTIVITY

SOLID STREAM (FRESH WATER)

Voltage	$1\frac{1}{8}$ -Inch Nozzle Safe Distance In Feet	$1\frac{1}{2}$ -Inch Nozzle Safe Distance In Feet
1,100	6	9
2,200	11	16
3,300	15	22
5,500	18	27
6,600	19	29
11,000	20	30
22,000	25	33
33,000	30	40

FOG STREAM (FRESH WATER)

Voltage	Safe Distance In Feet	Voltage	Safe Distance In Feet
7,500	.50	88,000	4.50
15,000	1.50	110,000	5.50
25,000	1.50	132,000	6.50
37,000	2.00	154,000	7.50
50,000	2.75	187,000	9.00
73,000	4.00	220,000	10.50